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ABSTRACT

This paper presents two general approaches to the assessment of knowledge structures, the first of which entails the building of empirical evidence to support cognitive theory. This type of assessment is concerned with attempting to prove the existence of various knowledge structures; that is, evidence that leads to the construct validity of these metaphorical ideas. The second approach is dependent upon the first task and attempts to look at the actual content within the structure. That is, assuming that such constructs (structures) exist, then what methods can be used to determine the specific relationships of ideas within a structure? Different types of knowledge representation are described, including propositions/semantic memory; productions; schemata/scripts, and images/episodic memory/iconic memory/spatial knowledge. Several methods for assessing structure are then presented for different types of representations, and it is noted that some of these techniques are concerned with proving the existence of the construct while others are used to assess the current content of the structure. A brief review of the issues involved in the assessment of knowledge structures concludes the paper. (23 references) (BBM)

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ASSESSING KNOWLEDGE STRUCTURES

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This paper presents two general approaches to the assessment of knowledge structures. The first approach entails the building of empirical evidence to support cognitive theory. This type of assessment is concerned with attempting to prove the existence of various knowledge structures, that is, evidence that leads to the construct validity of these metaphorical ideas. The second approach is dependent upon the first task and attempts to look at the actual content within the structure. That is, assuming that such constructs (structures) exist, then what methods can be used to determine the specific relationships of ideas within a structure?

DIFFERENT TYPES OF KNOWLEDGE REPRESENTATION

It will be helpful to distinguish between different assumptions regarding the representation of knowledge in memory. This will affect how this knowledge is structured, and consequently how it is assessed. There is not complete agreement in current cognitive psychology as to the exact definition of the terms that I have used, but I have grouped some common constructs together in an attempt to be parsimonious.

Propositions/semantic memory. This type of representation claims that knowledge is stored in a way that is not a direct representation of the outside world. Rather, knowledge is abstracted and stored in the form of propositions. These are relationships between *subjects* and *predicates*. Schank and Abelson (1977) have expressed the idea that there are a limited number of relationships that can be represented generically, in their Conceptual Dependency theory. Proposition representations are assumed to be declarative knowledge, that is, knowledge of "what" as opposed to knowledge of "how." (E. Gagne, 1985). This type of knowledge would equate with "verbal information" in R.M. Gagne's (1979) taxonomy and with the "remember" level in Merrill's (1983) Component Display Theory.

Productions. When knowledge can be applied, it can be thought of as existing in a production representation. This is a series of "if/then" statements that allows the subject to react to the outside world. Implicit in this representation form is the idea that an if/then statement can be linked to other if/then statements creating a *production system* (E. Gagne, 1985). A production system would underlie all complex forms of performance, both cognitive and

psychomotor. This type of knowledge would roughly equate with "intellectual skills" and "motor skills" in R.M. Gagne's (1979) taxonomy and the "use" and "find" levels in Merrill's (1983) Component Display Theory.

Schemata/scripts. Although the most ambiguous of the representation forms, a schema or a script can generally be thought of as knowledge of a prototypical situation. The situation activates an existing script or schema in which there are default values for the most typical variables that will be encountered in the situation. The learner can go beyond the information given by using these default values for both comprehension and creating inferences. Schemata and scripts are essential in the comprehension process, because they set up expectations of the environment regarding what to expect in a situation. More central actions may be more easily recalled and can be used as guides for top-down processing (Galambos, 1986). It would seem that a schema or a script could be thought of as an integrated system of propositions and productions since both need to interact in controlling perception, understanding, and behavior.

Images/episodic memory/iconic memory/spatial knowledge. There are similarities and differences between these ideas of representation forms. Essentially, each is based on the idea that knowledge may be stored in a literal "picture" form, as opposed to an abstracted representation such as a proposition.

KNOWLEDGE STRUCTURE

This section on assessing knowledge structure briefly details several methods for assessing structure assuming a proposition/semantic representation, a schema based representation, a production representation, and an iconic/episodic representation. As was previously mentioned, note that some of these techniques are concerned with proving the existence of the construct while others are used to assess the current content of the structure.

SEMANTIC/PROPOSITION REPRESENTATION

These tasks and tests do not reveal the specific contents of the propositions in memory. Rather, they seek to confirm the existence of this type of representation.

Reading time tests--This basic test is used to support the idea of propositions. A sentence is broken in propositions by the experimenter. The subject's reading time is measured. Reading time correlates strongly with number of propositions included in each sentence, because it is assumed that it takes time to process each different proposition. (Kintsch & Keenan, 1973, cited in Robertson, 1986)

Semantic recall tests--Subjects are given a paragraph to read. They are later shown sentences which are similar to some of the sentences contained in the original paragraph. The fact that subjects will often believe that they have seen a sentence that is similar in meaning--but not actually incurred in the paragraph--supports the idea that information may be stored in proposition form.

Hierarchical timing tests--It was assumed by Collins and Quillian (1969, cited in Norman, 1976) that learners structure knowledge of a concept in a hierarchical manner, with essential features at the higher levels. Lower levels contain only features that separate the item from other items at the same level. This was measured with timing tests, assuming that it took more time to process comparisons between items at different levels than it would take to compare parallel items in one of the branches of the hierarchy, because of the processing time needed to search through the hierarchy (E. Gagne, 1985). Although continued research evidence disproved much of this theory, the timing technique may still have value (see *generating examples*, below).

SCHEMATA/SCRIPTS/FRAMES AS REPRESENTATIONS

These tests are generally based on the assumption of semantic proximity, that is, that related ideas are stored close to each other in cognitive structure (Nagy, 1983). Most of these assessment procedures deal with integrated propositions, and occasionally propositions integrated with production systems.

Pattern notes--Subjects are given a word at the center of a blank page of paper and asked to free associate other words which are then linked together. However, the student-created linkages do not specify the relationships between the words. Pattern notes are scored by counting the number of links between words, and creating an intercorrelation matrix. This test has concurrent validity with word association tests (Jonassen, 1987).

Word association tests-- There are two types: (1) Free word association: subjects are given a word and asked to list the first word that comes to mind when thinking of the first word. Below it, the second word that comes to mind is listed, etc. Chaining is not allowed, and words are not to be repeated. This list is then correlated with the content structure (Preece, 1976). (2) Controlled word association: subjects are given lists of words and asked to rank order them according to which words are most related in meaning. (Jonassen, 1987).

Tree construction tasks-- Subjects are required to construct a linear graph in which the intersections are words and the connecting lines are the relationships. However, structures may be constrained by this type of pattern. (Jonassen, 1987)

Concept maps--Subjects are asked to link concepts that relate to other concepts in a hierarchical pattern. The links (representing the relationships between concepts) are then labeled. It is assumed that this is a "rubber" hierarchy, that is, that the sequence of connected concepts could be subsumed in several hierarchies of equal validity. Nowack and Gowan (1984) have devised a scoring system in which concept maps can be compared to content structure.

Membership decision tasks--This type of task attempts to determine the typical actions within a script. "Subjects are timed as they decide whether an action is involved in performing a given activity" (Galambos, 1986). Subjects are first given an action phrase followed by an activity phrase. The subject must

choose whether or not the action is a component of the activity. This measures the centrality of the action, that is, how important the action is to the activity.

Generating examples--Subjects are given a category and asked to generate members or instances of the category. The "production frequency" (the speed and order of generation of the instances) determines how closely any instance is related to the superordinate category. As related to Collins and Loftus (1975) spreading activation theory, one can determine that, "the greater the semantic relatedness of an instance and a category, the faster the decision that the instance is a member of the category." (Eysenck, 1987).

Conceptual models--These are essentially concept maps of content structure as compared to cognitive structure. These models contain node links representing concepts, and the linkages are labeled, for example, "is a consequence of; is one feature of, etc." (Neill, 1970 cited in Romiszowski, 1981). Although not used for assessing cognitive structure, this technique could easily be adapted.

Concept typicality ratings--In this task, subjects are given a superordinate category, and then asked to rate the typicality of different given instances of the category. It is assumed that more typical instances are more highly related--and in closer semantic proximity in structure--than less typical instances (Eysenck, 1987).

PRODUCTION REPRESENTATION

A production is closely related to the idea of information processing, and can also be thought of as the "executive subroutine" that controls psychomotor activities. A production is said to underlie all skilled performance, be it cognitive or physical.

Subtraction technique for assessing processing--These techniques are used to measure the time needed to complete various tasks. It is assumed that if the processing takes place as theorized, that this will correlate with the time needed to complete the mental task. By varying only one element of the task, and consequently determining a change in processing time, the experimenter infers that processing took place as theorized. This type of technique has been used to study information processing models of cognition and perception (E. Gagne, 1985)

Actual tasks--Because it is assumed that a production system underlies and controls skilled automatic performance, the absence of the skill, would point to an incomplete production system. According to R.M. Gagne (1979), to test for intellectual skills, the subject should be given novel instances of concepts to classify, or novel situations in which to apply a principle. Since production systems underlie these skills, if the subject is able to do so, then it is assumed that there is a production system in place that supports such action.

Think-Aloud tasks--In these tasks, the subject is asked to speak aloud his or her thoughts as he or she solves a problem or carries out an activity. The statements should be roughly parallel to the "code" of the production systems, and should follow the same logic. This was used by Gordon (1961) in his attempts to map out creative processes in inventors. Critics of the approach say

that speaking aloud may interfere with the actual production system, by making the subject self-conscious of otherwise unconscious mental activities.

Diagnostic tests--By carefully creating tests that measure the components of a process (rather than just the outcome) the production systems that are used by the subject can be inferred. This type of test is common in mathematics, when students are asked to "show your work." The teacher can then reason that because certain steps were omitted or incorrect, that these productions (or links to these productions within the overall production system) are faulty.

EPISODIC/ICONIC/SPATIAL REPRESENTATION

Scanning time--If knowledge is structured in a pictorial form, then it should take more time to scan a complex image than it would to scan a more simple image. This type of test asks the student to recall a particular image (for example, how many panes of glass there are in your bedroom windows). The time that it takes to answer is highly correlated with the complexity of the image (number of panes of glass), therefore supporting the idea that the subject actually "looked" at an image that was stored in memory and actually counted the panes of glass. (E. Gagne, 1985).

Cognitive maps--It is assumed that cognitive maps are independent of language and semantic representation because monkeys and white rats also have them (Eysenck, 1987). Tolman first measured the existence of these structures by placing animals in mazes, allowing them to run free, then placing rewards in various places while blocking off certain avenues (LeFrancois, 1982). Because the animals still chose the shortest path, Tolman reasoned that they used "maps" to find their way instead of stimulus-response chains or sequences.

Human mazes--To determine the subject's spatial abilities and sense of direction, subjects are put through a disorienting situation and then asked to point to a direction or object. In a 1977 study by Kozlowski and Bryant (cited in Smyth, Morris, Lvy, and Ellis, 1987) subjects were put through a maze consisting of tunnels beneath a university. The students with better sense of direction were able to improve their ability to indicate the starting point over several trials. Those with weaker sense of direction are unable to improve. Witkin's field dependent/field independent aptitude was assessed as an attempt to determine why WWII flyers sometimes got lost in the clouds. His earliest test used a movable chair and movable horizon (room) to determine whether subjects were able to spatially orient themselves to true vertical. Later tests expanded his original concept (Witkin, Moore, Goodenough, Cox, 1976).

Mental rotation tasks--A subject is given two pictures of an object, and asked to determine whether or not the first object can be rotated to look like the second object. This can be done with two or three dimensional pictures. Because it takes longer to answer the question the further the actual object would have to have been rotated, one determines that a form of spatial or pictorial knowledge structure exists. (E. Gagne, 1985; Smyth, Morris, Lvy, and Ellis, 1987).

ISSUES

In critiquing the general problems with most cognitive theories and indirectly the issue of increasing the construct validity of cognitive structure, Thorndyke (1981) has said that we need theories that are capable of making predictions that more clearly separate one theory from another. J.R. Anderson (1976) has called this the problem of nonidentifiability (E. Gagne, 1985). Interested readers should review these sources for a look at this continuing argument, which basically says that empirical findings can often be accounted for by several different theories.

In terms of these assessment techniques as a method of assessing the contents of an individual's cognitive structure, Nagy (1983) has called cognitive structure measurements "a blunt instrument." The next step is a method of determining the reasons for the links, connections, or similarities. Although this type of linkage labelling is dealt with in Nowack and Gowan's concept mapping procedure, few of the other techniques listed deal with this issue. Nowack and Gowan (1984) themselves state that, "how accurately concept maps represent either the concepts we possess or the range of relationships between concepts we know...can only be conjecture at this time." Although Jonassen's method of pattern noting has concurrent validity with word association tests, the construct validity of word association tests is still arguable.

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